

CLAIMS

- Jul*
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1. Apparatus for heart pacing with cardiac output modification, comprising:
one or more electrodes, which apply electrical signals to cardiac muscle segments; and
signal generation circuitry, which applies an excitatory electrical pulse to at least one of
5 the one or more electrodes to pace the heart and a non-excitatory stimulation pulse to at least
one of the one or more electrodes to modify the cardiac output.
2. Apparatus according to claim 1, wherein the circuitry synchronizes the non-excitatory
stimulation pulse with the pacing pulse.
- 10 3. Apparatus according to claim 2, wherein the circuitry introduces a predetermined time
offset between the pacing pulse and the non-excitatory stimulation pulse.
4. Apparatus according to claim 3, wherein the circuitry generates a sequence of multiple
non-excitatory stimulation pulses, at predetermined respective delays relative to the pacing
pulse.
- claim 1*
5. Apparatus according to ~~any of the preceding claims~~, wherein the one or more electrodes
comprise a bipolar non-excitatory stimulation electrode, across which the non-excitatory
20 stimulation pulse is applied.
- claim 1*
- AA* 6. Apparatus according to ~~any of claims 1-4~~, wherein the one or more electrodes comprise
a pacing electrode and a non-excitatory stimulation electrode, and wherein the non-excitatory
stimulation pulse is applied between the non-excitatory stimulation electrode and the pacing
25 electrode.
- claim 1*
- AA* 7. Apparatus according to ~~any of claims 1-4~~, wherein the signal generation circuitry is
encased in an implantable case.

8. Apparatus according to claim 7, wherein the non-excitatory stimulation pulse is applied between one of the one or more electrodes and the implantable case.

AX 5 9. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, and comprising at least one sensor, which senses cardiac activity, wherein the sensor is coupled to the signal generation circuitry, which generates the pulses responsive thereto.

10 10. Apparatus according to claim 9, wherein the signal generation circuitry interrupts application of the excitatory pulse, while generating the non-excitatory pulse responsive to the sensor.

11. Apparatus according to claim 9, wherein the at least one sensor comprises an electrode, which senses cardiac electrical activity.

15 12. Apparatus according to claim 11, wherein the circuitry detects a QT interval in the cardiac electrical activity.

13. Apparatus according to claim 9, wherein the sensor comprises a pressure sensor.

20 14. Apparatus according to claim 9, wherein the sensor comprises a flow rate sensor.

15. Apparatus according to claim 9, wherein the sensor comprises an oxygen sensor.

16. Apparatus according to claim 9, wherein the sensor comprises a temperature sensor.

25 17. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, wherein the signal generation circuitry varies one or more parameters of the non-excitatory stimulation pulse, from the group of parameters including voltage, current, duration, timing delay, waveform and waveform frequency.

- AA 18. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, wherein after the non-excitatory stimulation pulse, the signal generation circuitry generates another pulse of opposite polarity to the stimulation pulse, which is applied to the cardiac muscle segment by the non-excitatory stimulation electrode.
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- AA 19. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, wherein the one or more electrodes comprise at least one non-excitatory stimulation electrode having an area of at least 5 mm².
- 10 20. Apparatus according to claim 19, wherein the at least one non-excitatory stimulation electrode applies the stimulation pulse to a heart segment having an area of at least 1 cm².
21. Apparatus according to claim 20, wherein the at least one non-excitatory stimulation electrode comprises a net of addressable electrodes.
22. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, wherein the signal generation circuitry varies the extent of a portion of the area of the heart segment to which the non-excitatory stimulation pulse is applied.
- AA 20 23. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, and comprising a telemetry unit, which receives data indicative of cardiac function and programs the signal generation circuitry to adjust the pulses responsive to the data.
- AA 24. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, wherein application of the non-excitatory stimulation pulse engenders an increase in the cardiac output.
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- AA 25. Apparatus according to ^{claim 1} ~~any of claims 1-4~~, wherein application of the non-excitatory stimulation pulse engenders a decrease in the cardiac output.

42. A method according to claim 35, wherein applying the at least one sensor comprises applying an oxygen sensor.

43. A method according to claim 35, wherein applying the at least one sensor comprises applying a temperature sensor.

44. A method according to claim 35, wherein generating the pulse comprises receiving signals from the sensor via telemetry, and varying a parameter of the pulse responsive thereto.

AA 10 45. A method according to *claim 27* ~~any of claims 27-29~~, wherein applying the electrodes comprises applying electrodes so as to convey the non-excitatory pulse to a segment of the heart having an area of at least 5 mm².

46. A method according to claim 45, wherein applying the electrodes comprises applying electrodes so as to convey the non-excitatory pulse to a segment of the heart having an area of at least 1 cm².

47. A method according to claim 46, wherein applying the electrodes comprises applying electrodes so as to convey the non-excitatory pulse to a segment of the heart having an area of at least 4 cm².

AA 48. A method according to *claim 27* ~~any of claims 27-29~~, wherein conveying the non-excitatory pulse comprises varying an area of the heart to which non-excitatory pulses are applied.

AA 25 49. A method according to *claim 27* ~~any of claims 27-29~~, wherein conveying the non-excitatory pulse comprises varying one or more parameters of the pulse from the group of parameters including voltage, current, duration, timing delay, waveform and waveform frequency.

AA 30 50. A method according to *claim 27* ~~any of claims 27-29~~, and comprising after conveying the non-excitatory pulse to the at least one of the one or more electrodes, conveying another pulse of opposite polarity thereto to the electrodes.

claim 1
26. Apparatus according to ~~any of claims 1-4~~, wherein application of the non-excitatory stimulation pulse increases an efficiency of cardiac contraction.

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27. A method for heart pacing with modification of cardiac contraction, comprising:
applying one or more electrodes to a subject's heart;
conveying an excitatory electrical pulse to at least one of the one or more electrodes to pace the heart; and
conveying a non-excitatory stimulation pulse to at least one of the one or more electrodes to modify an efficacy of cardiac contraction.

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28. A method according to claim 27, wherein conveying the non-excitatory stimulation pulse comprises synchronizing the pulse with the excitatory pacing pulse.

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29. A method according to claim 28, wherein synchronizing the non-excitatory stimulation pulse comprises controlling a time offset of the pulse relative to the pacing pulse.

claim 27
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30. A method according to ~~any of claims 27-29~~, wherein conveying the excitatory and non-excitatory pulses comprises conveying the pulses to a common one of the one or more electrodes.

claim 27
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31. A method according to ~~any of claims 27-29~~, wherein applying the one or more electrodes comprises implanting a pacing electrodes in a first chamber of the heart and implanting a non-excitatory stimulation electrode in another chamber.

claim 27
32. A method according to ~~any of claims 27-29~~, wherein applying the one or more electrodes comprises implanting a plurality of electrodes in a single chamber of the heart.

~~33. A method according to ^{claim 27} ~~any of claims 27-29~~, wherein applying the one or more electrodes comprises implanting at least one non-excitatory stimulation electrodes in each of a plurality of chambers of the heart.~~

~~34. A method according to ^{claim 27} ~~any of claims 27-29~~, wherein applying the one or more electrodes comprises fixing an electrode to the epicardium.~~

~~35. A method according to ^{claim 27} ~~any of claims 27-29~~, and comprising applying at least one sensor to the subject's body, which senses cardiac activity, and wherein conveying the non-excitatory stimulation pulse comprises generating a pulse responsive to the activity.~~

~~36. A method according to claim 35, wherein applying the at least one sensor comprises implanting at least one sensing electrode in the heart.~~

~~37. A method according to claim 36, wherein generating the pulse comprises detecting a QT interval in an electrical signal received by the sensing electrode and generating a pulse responsive thereto.~~

~~38. A method according to claim 35, and comprising interrupting the conveyance of the excitatory pulse while conveying the non-excitatory pulse responsive to the activity.~~

~~39. A method according to claim 35, wherein applying the at least one sensor comprises applying a body surface electrode to the subject.~~

~~40. A method according to claim 35, wherein applying the at least one sensor comprises applying a flow sensor.~~

~~41. A method according to claim 35, wherein applying the at least one sensor comprises applying a pressure sensor.~~

AA 51. A method according to ~~any of claims 27-29~~, wherein modifying the efficacy comprises increasing the cardiac output. *claim 27*

AA 52. A method according to ~~any of claims 27-29~~, wherein modifying the efficacy comprises decreasing the cardiac output. *claim 27*

*A 53. A method according to ~~any of claims 27-29~~, wherein modifying the efficacy comprises enhancing the efficiency of cardiac contraction. *claim 27*

